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The Outcome of STEM Education-Based Learning Using an Engineering Design Process with Training Packages for Industrial Internet of Things (IIoT) in Vocational Thailand

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Abstract. This research aimed to develop science, technology, engineering and mathematics (STEM) education-based learning using an engineering design process with Training Packages for use in the Industrial Internet of Things (IIoT) in vocational Thailand. The purposive sample consisted of 134 participants who were vocational certificate students in Thailand, selected using a quasi-experiment framework with a one-group pretest and posttest design method. The research tool consists of 1) the training packages, 2) the achievement test, and 3) the student satisfaction assessment form. The statistical approaches involved the Mean (M), standard deviation (SD.), and t-test for the dependent samples. The research results found that 1) the evaluation result of the training packages is at a high level (M = 4.64, SD. = 0.13), 2) the evaluation result of the STEM education-based learning using the engineering design process is at a high level, 3) the learning achievement of students after studying is significantly higher than before studying at a statistically significant level of .05. ($p<.05$), and 4) the students are highly satisfied with STEM education-based learning using the engineering design process with training packages for Industrial Internet of Things (IIoT) (M = 4.50, SD. = 0.28). The practical implication of the developed STEM education-based learning is that it can effectively promote the knowledge and skills required for engineering skills.

Keywords: Engineering Design Process; Training Packages; STEM education; Industrial Internet of Things

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1. Introduction

Industry 4.0 in Thailand (Belmonte et al., 2023; Siddoo et al., 2019) is widely prepared to transform classical factories into smart factories. (Adebanjo et al., 2023). Preparing a highly skilled workforce for Thailand's industrial sector is crucial as part of strengthening the country's development, enabling it to appropriately adapt to the impacts of changes (Adebanjo et al., 2023). Modern factories have implemented automation technology to control industrial machinery (Banmairuroy et al., 2022; Gualtieri et al., 2024). The goal is to manage industrial operations by maintaining various parameters, such as temperature, pressure, and position detection. To achieve the specified values, industries are required to meet global standards. The automatic control systems used in most industrial factories are controlled by programable logic control (PLC) (Borrett & Beckerleg, 2024). The advantages of using PLCs include reducing the size of the control system, replacing wiring with programming, easily changing circuits, expanding systems, and ease of maintenance.

In the post-COVID educational system, industrial vocational students learning online lack practical skills and possess professional competencies that do not align with the rapidly changing technological advancements (Kareemullah et al., 2023). Industrial vocational students are a crucial workforce in the industrial sector, resulting in a shortage of skilled technicians who possess knowledge that aligns with the needs of enterprises (Lozano-Osorio et al., 2024; Zhang et al., 2024). Additionally, the educational equipment is insufficient and simulated work laboratories are lacking. Industrial students are a vital workforce in the industrial sector, resulting in a shortage of skilled workers whose knowledge meets the needs of establishments, as well as there being insufficient educational equipment and no virtual simulation laboratories.

The Ministry of Education of Thailand has a policy to promote student development in innovation creation (Ladachart et al., 2019). STEM education is an educational approach that fosters fundamental competencies for students in innovation development (Cotabish et al., 2013). STEM education is an integration of knowledge across four disciplines: science, engineering, technology, and mathematics (Wang & Wang, 2023; Zhong et al., 2024). The engineering design process is a crucial component of the learning process (Cotabish et al., 2013). The engineering design process is a systematic approach used for product development and problem-solving. This process serves as a crucial tool in effectively fostering analytical thinking skills, problem-solving abilities, creative thinking, and collaborative skills among students effectively. (Sopakitiboon et al., 2023).

This research innovates training packages for the Industrial Internet of Things (IIoT) that focus on learning using the engineering design process with STEM education for vocational students in Thailand. The engineering design process consists of six steps: problem identification, related information search, solution design, planning and development, design improvement, and presentation. Students gain practical skills and acquire professional competencies that align with industry requirements.

1.1 Research Objectives

1. To construct training packages for the Industrial Internet of Things (IIoT).
2. To develop the process of teaching and learning in the form of STEM education-based learning using the engineering design process.
3. To evaluate the vocational students' learning outcomes using training packages integrated with STEM education which emphasises the engineering learning process.
4. To monitor student engagement with the training packages integrated with STEM education which emphasises the engineering learning process.

1.2 Research questions

The training packages for IIoT using STEM education emphasising the engineering learning process were evaluated using the following research questions:

- RQ1: Does the developed training package and STEM education have a quality that is suitable for training?

- RQ2: How does STEM education, which emphasises the engineering learning process (Aziz et al., 2022; Sadam & Al Mamun, 2024), help students integrate knowledge from various fields into the IIoT?

- RQ3: Can the training packages and STEM education that emphasise the engineering learning process enhance the student's learning achievements? (Pimdee et al., 2024; Shen, 2024)?

- RQ4: How do the students engage (Ferreira et al., 2024; Henry et al., 2021) with the training packages and STEM education that emphasises the engineering learning process?

1.3 Research hypotheses

The study proposes the following hypothesis:

- The students' learning achievement after learning will be higher than before with a statistical significance at the .05 level.
- Student satisfaction with the training packages and STEM education will be at a high level of satisfaction.

2. Training Course Analysis

In this study, the analysis of the training curriculum begins with a survey of the needs of the industrial and educational sectors in Thailand drawing on the views of experts, revealing that: 1) the survey of workforce skill requirements (Deekaew & Chomsuwan, 2021) conducted through interviews with experts in Industry 4.0 identified essential skills such as PLC programming, IoT system management, SCADA operation, and automation control. These skills are crucial in addressing the growing demand in Thailand's industries, including smart farming, smart factories, and intelligent transportation systems. Notably, the industrial workforce is largely comprised of vocational education students. 2) The analysis of the learners' knowledge and skills reveals that most students lack a foundational understanding of the Industrial Internet of Things (IIoT), which is necessary to begin instruction with fundamental topics, such as the operation of

IoT networks and the basic use of devices. The students lack opportunities for hands-on practice in scenarios that closely mimic real industrial environments, and the teaching process should focus on activities that foster practical and experiential learning. From the survey of the training curriculum development needs and recommendations from experts, it was found that:

Developing a training curriculum tailored for the application of the Industrial Internet of Things (IIoT) to enhance its relevance to industry requires the integration of knowledge from science, technology, engineering, and mathematics with practical applications in Industrial Internet of Things (IIoT) systems. This approach is essential for preparing the workforce for Industry 4.0 by emphasising a fundamental understanding of IoT concepts such as device configuration, data management, and real-time processing. The students gain an understanding of the application of these technologies in industrial contexts, such as enhancing factory efficiency, implementing smart farming systems, and automating production processes.

Developing teaching and learning approaches that encourage students to engage in hands-on activities, aligning their practical work with real-world scenarios in the industrial sector, such as the design of a smart farm system integrated with the Industrial Internet of Things (IIoT), the development of an energy control system in factories, etc. The students engage in diverse activities that enhance their motivation and develop essential skills, such as analytical thinking, systematic problem-solving, teamwork, and communication.

Development of Industrial Internet of Things (IIoT) Training Packages that align with the practical skills required in the workplace, addressing both current demands and future trends. This approach enhances the students' confidence and improves their readiness to enter a highly competitive labour market.

The design of the training content in this research includes the IoT architecture, IoT gateway, input/output devices, and supervisory control and data acquisition (SCADA) (Sonsiri et al., 2019; Vargas-Salgado et al., 2019), as shown in Figure 1.

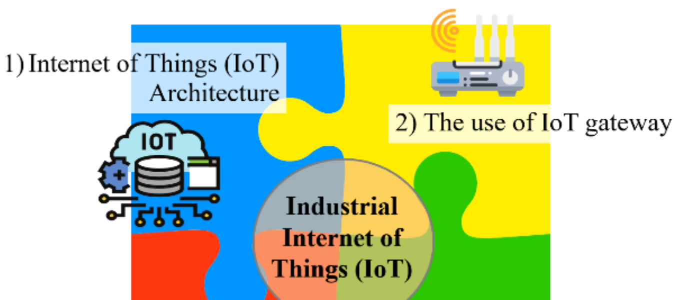


Figure 1: Training content for the Industrial Internet of Things training set

3. Training Course Analysis Developing the Process of Teaching and Learning in STEM Education

In this study, the design of the STEM education framework including factors related to STEM education management can be conceptualised into four components: goals, the nature and scope of integration, implementation, and outcomes, as shown in Figure 2. The goals involve setting the objectives of the research, which include STEM literacy, 21st competencies, workforce readiness, and interest and engagement. The nature and scope of integration involves defining the content boundaries of IoT for the industrial sector for vocational certificate students in the appropriate fields. The implementation details encompass instructional design, trainer assistance, learning adaptation, and the learning environment for IIoT applications. The outcomes cover a comprehensive overview of the learners' knowledge, learning achievements, and their satisfaction with the implemented learning model.

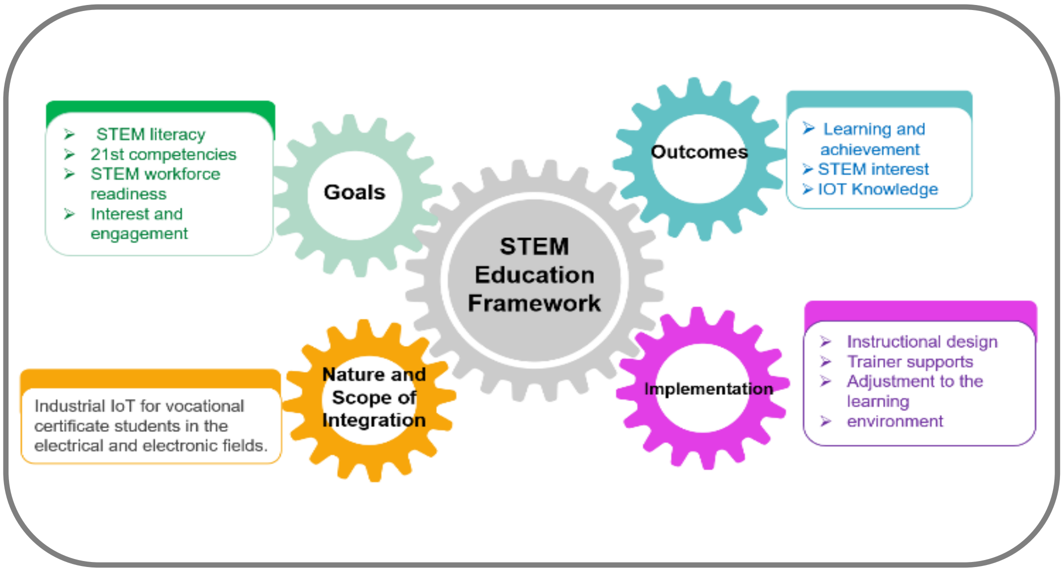


Figure 2: Training content for the Industrial Internet of Things training set

The conceptual framework from the design phase is shown in Figure 3. The STEM education learning model emphasises the engineering learning process along with the integration of IoT content and the four disciplines (science, technology, engineering, and mathematics). The engineering learning process consists of 6 steps: problem identification (P), related information search (R), solution design (S), planning and development (P), design improvement (D), and presentation (P). The engineering learning process learning steps are as shown in Table 1 which shows the details of the learning process and the learning activities for each step. The STEM education activity is as shown in Table 2, including the content characteristics and learning activities for each discipline.

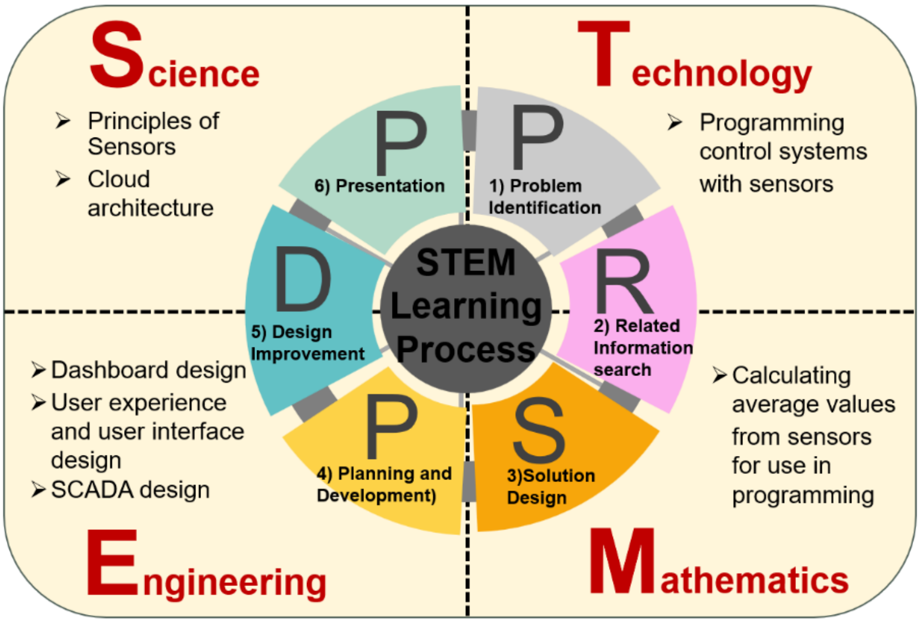


Figure 3: Design of the learning model for STEM education

Table 1: Engineer's learning steps and the learning process and learning activities.

Learning Steps	Details of the learning process	Learning activities
Step 1: Problem Identification (P)	The teacher presents the situation of the problem that is close to the student. Students consider the problem or sub-activity and then analyse the problem to find guidelines to solve the problem.	Solve the problem of electrical energy appropriately and efficiently, addressing temperature suitability and person detection.
Step 2: Related Information Search (R)	Students collect information through research and various activities to understand concepts in mathematics, science and technology to apply to solve problems.	Research from documents and learning resources such as websites, content sheets, etc.

Learning Steps	Details of the learning process	Learning activities
Step 3: Solution Design (S)	Students utilise the knowledge and concepts acquired from the research and data collection to design methods, projects, and problem-solving approaches. The students must reference the scientific, mathematical, and technological knowledge that they have gathered to evaluate and make decisions, and use this knowledge to outline the problem-solving methods.	Divide into groups, divide the work, exchange ideas, and jointly design the methodology.
Step 4: Planning and Development (P)	Students proceed to create a prototype as designed. In addition, they define the sub-steps of the work, and set goals for the period as part of implementing each step.	Create hardware and software, map sensor tags, and create a user experience (UX) and user interface (UI) dashboard.
Step 5: Design Improvement (D)	Students test the effectiveness of the project or problem-solving method and observe any issues that arise during testing. Students enhance the efficiency of the project.	Test the compatibility of the developed hardware and software such as the power control system and temperature control system.

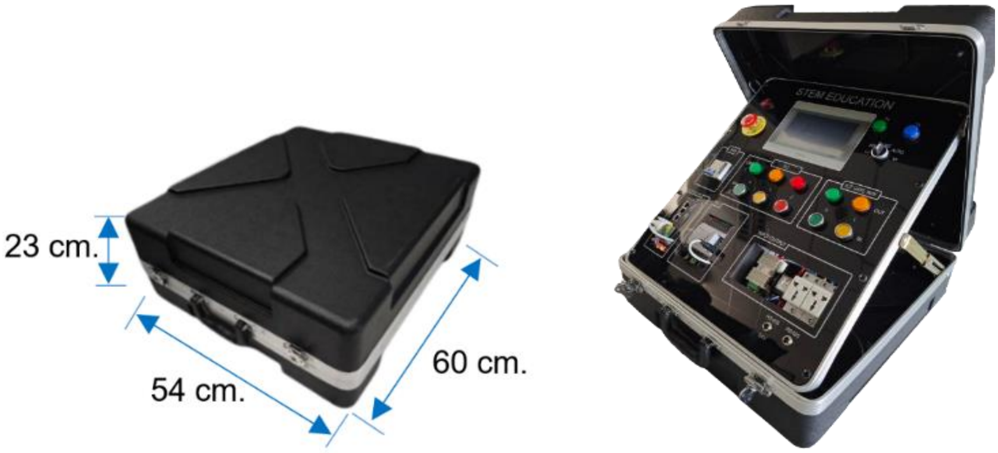
Table 2: STEM education activity.

Integration	Content characteristics	Learning activities
Science (S)	Learn the scientific basics related to IoT and sensors such as the operation of the sensors and principles of IoT.	Learn about the sensors to measure temperature, light, humidity, wattmeter, and the power factor.
Technology (T)	Learn about the technologies used in IoT such as basic programming, connecting the device, and related software.	Learn to program using the IoT gateway to control the pilot lamp, PLC and switch.
Engineering (E)	Design and build a dashboard for the IoT system, sensor, and temperature control system.	Design and build a temperature control system using cloud IoT to create a working system, such as a temperature and humidity control system for power management.
Mathematics (M)	Read the sensor to calculate the average and use the acquired average for logical decisions in the programming.	Analyse the temperature data measured by the sensor to calculate the humidity value and use the measured value from the sensor as basic data for programming.

4. Training Packages

4.1 Experimental Set

The experimental set for the IIoT structure was designed to support mobility (Ahmed et al., 2023), with carrying ease. The safety standard uses an emergency switch and circuit breaker. The training kit is designed as a metal box measuring 54 × 60 × 23 cm. Additionally, it can be adjusted from 0 to 60 degrees to facilitate the convenient viewing of various parameters, as illustrated in Figure 4. The internal structure is comprised of a circuit breaker and power meter, IoT gateway, alert system, monitor (HMI), status switch, input/output IoT gateway, and input/output for PLC as in Figure 5.



(a) Box size (b) Side view

Figure 4: The developed experimental set

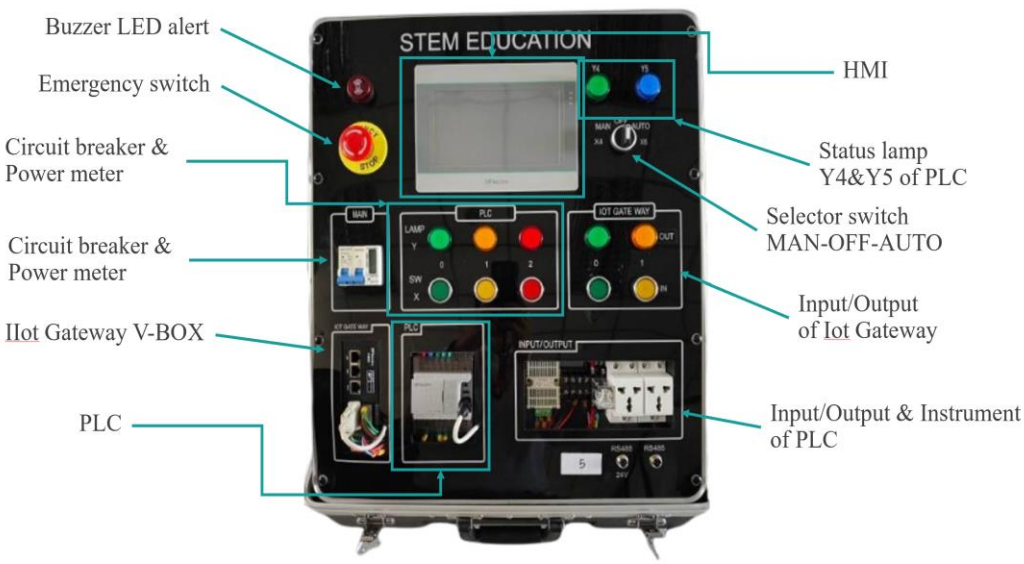


Figure 5: Front view of the experimental set

4.2 Web service platforms

The web service platform located at https://asean.v-box.net/ managed the input and output devices in the IIoT training media (Alulema et al., 2023), as shown in Figure 7. The service included two modules. The first module was a device-list panel that shows all devices linked to each IoT gateway.

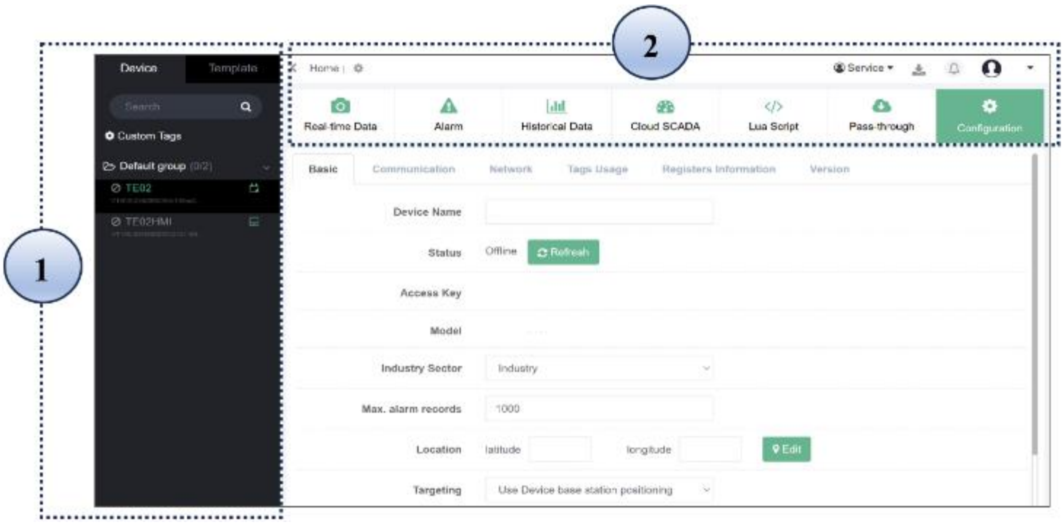


Figure 6: The home page of the web service platforms

The second module, on the top panel, processes real-time data from the input and output to display its key values. The power meter (PM) tab shows frequency, voltage, current, and power. The teacher assigned students to groups based on the component functions (Figure 7). Cloud SCADA (Dangwal et al., 2024) serves as a dashboard developed via Web Cloud Config (Figure 8). Virtual instruments like switches, indicators, and graphs were designed based on behaviour. The vocational students were tasked with creating a dashboard.

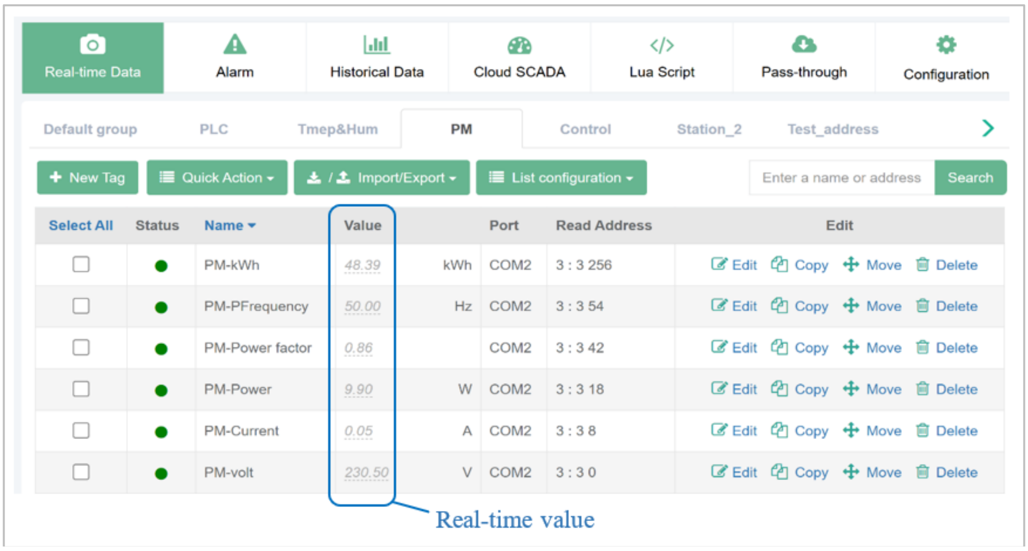


Figure 7: Real-time service for the IIoT learning package

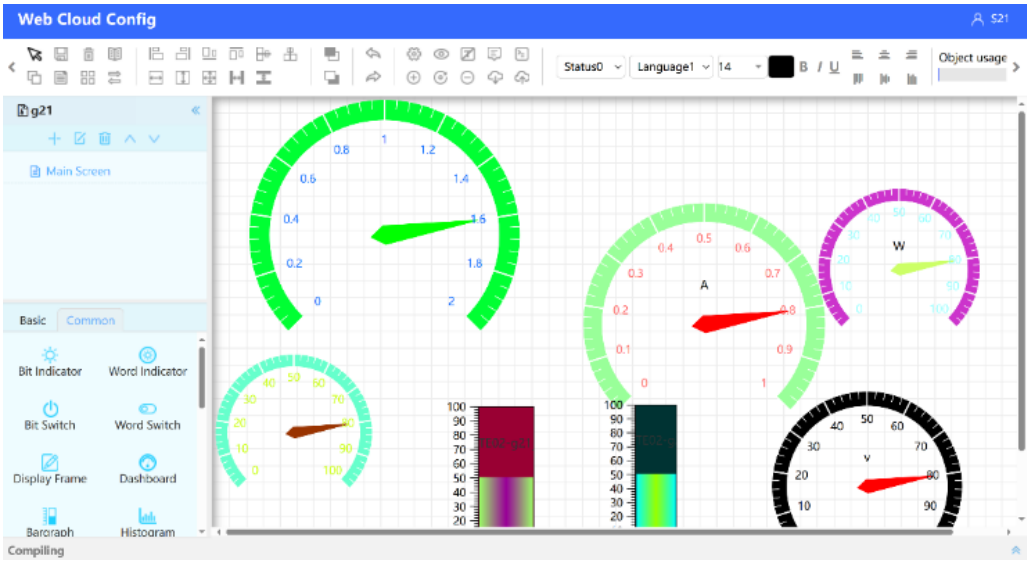


Figure 8: SCADA for the IIoT learning package

5. Methodology

5.1 Research Design

The research design used in this study was a quasi-experiment with a one-group pretest and posttest design, as shown in Fig. 11. Observation#1 (O1) evaluated students using a pretest (30 questions). Following treatment (X), the learners were assessed using observation#2, a posttest (30 questions). Both observations were used to estimate the students' learning achievement. To maintain consistency, both tests utilised identical questions (Al Hakim et al., 2022).

Figure 9: Research design

5.2 Participants

The participants consisted of 134 vocational certificate students from Thailand who were studying the electrical and electronic program in 2023. Table 3 lists the participant data for each college or school. The study used a quasi-experiment design with a one-group pretest and posttest method where the duration of learning was one day (and eight hours). All participants in this study provided consent for picture publishing. Parental agreement was gained prior to the data collection. The investigative process was carefully described to the parents. The investigation acquired authorisation from the institute director. The experimental process was approved by the Human Research Ethics Committee of the STEM Education Center, King Mongkut's University of Technology North Bangkok, Thailand (Reference Number: KMUTNB-STEM-20-03-2567).

Table 3: Participant data.

College/School	Number of participants
Thai-German, Pre-Engineering School	23
Mahasarakham Technical College	21
Khon Kaen Technical College	46
Phetchabun Technical College	21
Roi Et Technical College	23
Total	134

5.3 Research Tool

The research tools for STEM education-based learning using an engineering design process with training packages for Industrial Internet of Things (IIoT) in vocational Thailand were as follows:

- The training packages consisted of an experimental set, teaching plan, manual, and lab sheets, as shown in Fig. 10, all of which were evaluated for quality by a panel of seven experts.
- The achievement test consisted of four multiple-choice sections with 30 questions, each worth one point (30 points in total). The questions and corresponding behavioural objectives were assessed for content validity by seven experts. The Item-Objective Congruence (IOC) values ranged from 0.50 to 1.00, with values of 0.50 and above considered acceptable within the established criteria.
- Questionnaire on the students' satisfaction with the activity training packages, divided into two parts: Part 1 was a rating scale questionnaire with a 5-option rating system as shown in Table 4. (Poonputta & Nuangchalerm, 2024) (Sisamud et al., 2025), while part 2 consisted of open-ended questions.

Table 4. Range of average scores and interpretation of the results

Range of average scores	Interpretation of appropriateness.
4.50 – 5.00	Very high level of satisfaction
3.50 – 4.49	High level of satisfaction
2.50 – 3.49	Average level of satisfaction
1.50 – 2.49	Low level of satisfaction
0.00 – 1.49	Lowest level of satisfaction

5.4 Research procedure

The experimental procedure following the research plan took a day and eight hours with a sample group consisting of 134 students. The participants completed a pretest consisting of 30 questions prior to instruction. At the end of the training, the participants undertook a 30-question achievement test to evaluate their training achievement. To maintain consistency, the pretest and posttest consisted of identical questions as follows:

- Defining the training content, including the IoT architecture, IoT gateway use, connecting input/output devices, and SCADA, as described in Fig. 1.
- The design of the learning model of STEM education for the IIoT in Fig. 3 emphasises the engineering learning process along with the integration of IoT content and the four disciplines (science, technology, engineering, mathematics). The engineering learning process consists of 6 steps: 1) problem identification (P), related information search (R), solution design (S), planning and development (P),

design improvement (D), and presentation (P). This is followed by the design learning activity of the engineer learning process steps and the STEM education activity.

- Create the research tools and assess their quality using seven experts.
- Analyse the results using statistical values: the t-test followed the pre-test and posttest data, and the student satisfaction assessment was examined using mean value and standard deviation (SD). The study compared the results of the pretest and posttest achievements. The satisfaction with the training packages for IIoT using STEM education was evaluated using descriptive statistics.

6. Research Results

6.1 The quality of the training packages for Industrial Internet of Things (IIoT)

The training packages for Industrial Internet of Things (IIoT) were evaluated by seven experts who have teaching experience in the fields of electricity, electronics, and automation, as shown in Figure 10. The topics evaluated were the hardware design and learning documents. The result quality is of a high level (M=4.64 and SD.=0.13)

6.2 The quality of the learning process for STEM education and the engineering design process

Before conducting the on-site instruction, the designed training packages for IIoT using STEM education underwent a quality assessment by experts. Topics for assessment included the organisation of training activities, measurement, and evaluation, as shown in Figure 10. The organisation of training activities was at a high level and appropriate (M=4.39, SD.=0.13). Measurement and evaluation were also to a high level and appropriate (M=4.36, SD.=0.38).

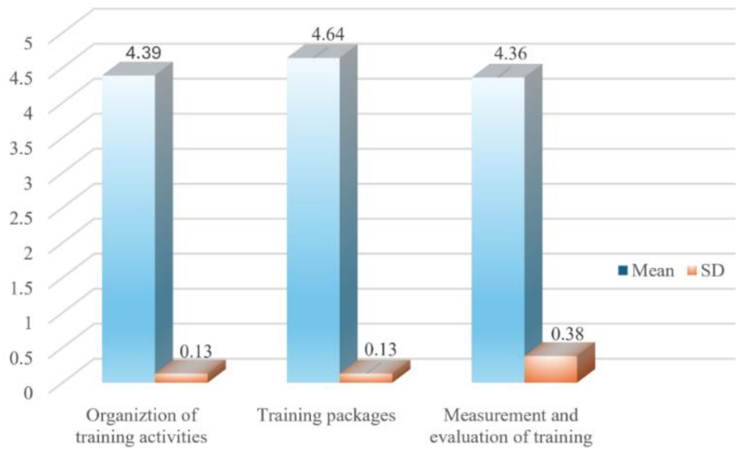


Figure 10: The quality of the developed training packages for IIoT using STEM education

The overall quality of the IIoT training packages using STEM education was appropriate at a high level (M=4.46, SD.=0.15).

6.2 Learning Achievement

In this study, paired sample tests were utilised to assess learning achievement by comparing the pretest and posttest scores for the students. This involved 134 students who took a 30-question pre-training test and conducted the training according to the process. After completing the training, students took a 30-question post-training test. The data was collected and analysed using the t-test dependent (Intasena & Worapun, 2024). The results of the large-scale experiment are presented in Tables 5 to 9, showing there to be significant differences in learning performance for each school (p< .05).

Table 5. The learning achievement of the Thai-German Pre-Engineering School (N=23)

Achievement	score	Mean	SD.	*t*	df	p^*
Pretest	30	16.09	4.54	9.75*	22	0.000
Posttest	30	25.17	3.64			

**p < .05, one-tailed*

Table 6. The learning achievement of Phetchabun Technical College. (N=21)

Achievement	score	Mean	SD.	*t*	df	p^*
Pretest	30	14.33	4.15	10.30*	20	0.000
Posttest	30	23.14	4.53			

**p < .05, one-tailed*

Table 7. The learning achievement of Khon Kaen Technical College. (N=46)

Achievement	score	Mean	SD.	*t*	df	p^*
Pretest	30	14.28	3.91	13.56*	45	0.000
Posttest	30	22.15	3.78			

**p < .05, one-tailed*

Table 8. The learning achievement of Roi Et Technical College. (N=21)

Achievement	score	Mean	SD.	*t*	df	p^*
Pretest	30	13.48	3.22	12.84*	20	0.000
Posttest	30	21.86	4.13			

**p < .05, one-tailed*

Table 9. The learning achievement of Mahasarakham Technical College. (N=23)

Achievement	score	Mean	SD.	*t*	df	p^*
Pretest	30	13.35	2.87	13.80*	22	0.000
Posttest	30	22.04	3.11			

**p < .05, one-tailed*

The overall learning achievement of all schools (N=134) is shown in Table 10. The results showed significant differences in learning performance (p< .05) with t=26.20 (p< .05). After the procedure, the students' average scores increased from

14.31 to 22.76, implying that training can enhance their knowledge and that there will be less variation in the mean scores.

Table 10. The learning achievement of students.

(N=134)

Achievement	score	Mean	SD.	*t*	df	*p**
Pretest	30	14.31	3.86	26.20*	133	0.000
Posttest	30	22.76	3.96			

**p* < .05, one-tailed*

Figure 11 illustrates the data-scattering characteristics for the entire student cohort (N=134). The pretest group (blue dot) was markedly lower compared to the posttest group (orange dot). Although the students showed improved learning outcomes after the test, some students still require additional support to acquire the necessary skills for future industrial work.

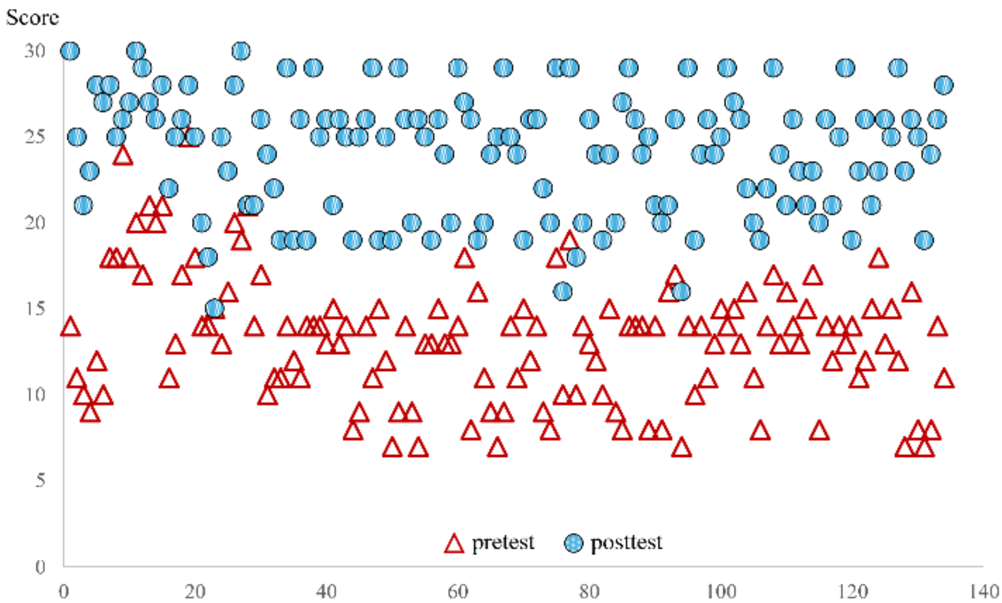


Figure 11: Scatter plot of the pretest and posttest data

6.3 Satisfaction Evaluation of the Participants

The satisfaction of the vocational participants from the five schools (Thai-German Pre-Engineering School, Mahasarakham Technical College, Khon Kaen Technical College, Phetchabun Technical, and Roi Et Technical College) was assessed after training using the training package with STEM education. After completing the learning achievement process, the researcher assessed the participants' satisfaction using a questionnaire that included the following evaluation topics: the training package and training activities, utilisation, and measurement and evaluation.

Table 11 shows the results of the evaluation of the participants' satisfaction in terms of the training packages for IIoT using STEM education. The overall student satisfaction with the set of media was at a very high level (M=4.50, SD.=0.28). The training activities were found to be interesting with a very high level of satisfaction (M=4.75, SD.=0.47). This was followed by satisfaction with the training packages to support learning, which was also at a very high level (M=4.73, SD.=0.49). The students were mostly satisfied with the training packages and training activities (M=4.67, SD.=0.42). Regarding utilisation, the benefit to further study received very high satisfaction (M=4.73, SD.=0.49). The benefit to future work was also rated as very high (M=4.74, SD.=0.46). The students were satisfied with the overall utilisation (M=4.66, SD.=0.42). In the measurement and evaluation, the assessment focused on authentic assessment, which received a high level of satisfaction (M=4.32, SD.=0.61). The duration of the evaluation period was appropriate, resulting in high satisfaction (M=4.25, SD.=0.67). The students were the most satisfied with the measurement and evaluation (mean=4.18, SD=0.32). The results comparing the average satisfaction levels of the trainees from five schools are shown in Figure 12.

Table 11. Satisfaction evaluation of the students (N=134)

Topics	M	SD.	Interpretation
Training Packages and Training Activities			
1. Training activities are interesting	4.75	0.47	Very high
2. Training packages to support learning	4.73	0.49	Very high
3. Training activities are diverse	4.55	0.12	Very high
4. Process of content transmission focuses on programming skills in the 21^{st} century.	4.68	0.51	Very high
5. Trainees participate in the learning activities.	4.58	0.55	Very high
Average	4.67	0.42	Very high
Utilisation			
6. Implementation in learning	4.63	0.60	Very high
7. Application in further study	4.73	0.49	Very high
8. Application in daily life	4.52	0.66	Very high
9. Future work	4.74	0.46	Very high
Average	4.66	0.42	Very high
Measurement and Evaluation			
10. Evaluation covers the training objectives	4.15	0.72	High
11. Assessment focuses on authentic assessment.	4.32	0.61	High
12. Evaluation is clear	4.00	0.67	High
13. Duration of the evaluation period is appropriate	4.25	0.67	High
Average	4.18	0.32	High
Total average	4.50	0.28	Very high

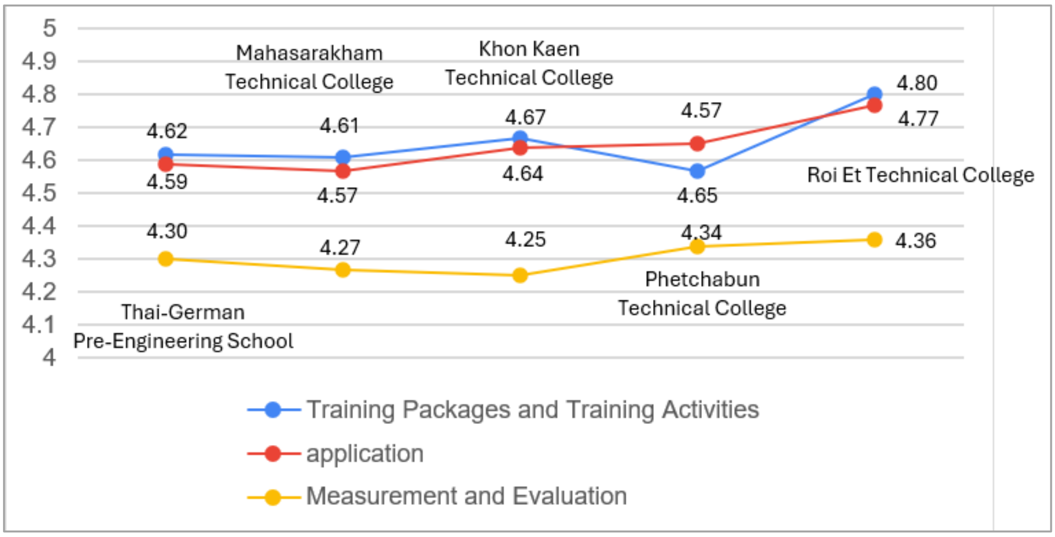


Figure 12: Comparing the average satisfaction levels of the trainees from 5 schools

7. Discussion

This study's importance was focused on STEM education-based learning using an engineering design process with training packages for the Industrial Internet of Things (IIoT) in Vocational Thailand. This part examines the experimental outcomes. The findings answer the research questions.

7.1 RQ1: Does the developed training package for the Industrial Internet of Things (IIoT) have a quality that is suitable for training?

According to the results, the quality is of a high level because the developed training package corresponds to the learning objectives and activities. The modern design and mobility are advantageous for real-world problems. Learning difficulties span the range from simple to complex. This corresponds to the findings (Voicu et al., 2022).

7.2 RQ2: How does STEM education-based learning using the engineering design process help students integrate knowledge from various fields in the IIoT?

The training package was created with a methodology emphasising the engineering learning process. Additionally, the instructional media for the IIoT was able to stimulate the students' motivation in the learning process and make it convenient to use. This corresponds to research (Montesdeoca & Rivera, 2023) that investigated the development of a training package for IIoT systems. The first and second research objectives of this investigation are achieved by the answer to RQ2.

7.3 RQ3: Can STEM education-based learning using the engineering design process with training packages for the Industrial Internet of Things (IIoT) enhance student learning achievements?

The onsite teaching results from five schools demonstrated the level of student engagement with the activities using training packages integrated with STEM education focused on the IIoT training package. The posttest comparison of the students' learning achievement was significantly higher than the pretest scores at the .05 significance level, validating the first hypothesis as described in Table 10. Theory combined with practice follows sequential steps according to the training plan that is designed to cover the content in line with the third research objective. The principles and components involved in producing the training packages systematically align with the results of the study (Al Hakim et al., 2022), which incorporates a systematic process for designing and developing said training packages.

7.3 RQ4: How do students engage with STEM education-based learning using the engineering design process with training packages for the Industrial Internet of Things (IIoT)?

The evaluation results for trainee satisfaction with the educational administration indicated they are extremely satisfied. The training program that has been developed enables participants to engage in industrial control tasks, which motivates them to learn. The students were actively engaged in practical activities, using knowledge and skills from relevant fields to solve real-world challenges. Additionally, they collaborated with teammates to accomplish the group assignments. The final hypothesis and research objective were confirmed by the students, as indicated by the data in Table 11. The learners expressed satisfaction with the software, hardware, and educational experience.

8. Limitations and Practical Implications

This study had the following constraints:

- The learning package has input and output components that require computers for programming and linking to the internet. The next version should integrate a single-board computer, Raspberry Pi, running a Linux operating system conveniently. The keyboard and mouse will be included in the training set.
- The experimental packaging is made from metal to protect the industrial components. The total weight of the experimental set is quite heavy. Subsequently, this may be reduced by using plastic case in the next generation.
- To increase the capability of the learning package, an auxiliary box should be created for specific IIoT operations, including the sensors and components.
- The learning package requires an AC220V power supply for operation and is restricted to indoor use only. The updated version should integrate an internal battery inside the experimental box for outdoor teaching activities.

The conclusions of the practical implications in this investigation are as follows:

- The training package can be used for other subjects in vocational colleges, such as control systems, industrial management, and programmable logic control.
- A meta-disciplinary framework using an IIoT learning package for vocational students provides extensive relevance. Consequently, active learning models, including problem-based and project-based learning, can be potentially applied to provide IIoT learning packages and enhance the students' learning achievements.

9. Conclusions

The findings have developed the IIoT training package for STEM education for vocational students in Thailand. The training box is a unique design to facilitate industrial application. The tailored design incorporates an IoT gateway and an electrical instrument. SCADA with LUA programming language was applied to operate the IIoT training package over the IoT cloud network. A PLC was used to run the input and output components. The HMI was included as a control panel. The core method of communication used the RS-485 protocol to link all modules. The learning package is a portable unit that is appropriate for on-site teaching.

The training content was divided into four units: IoT architecture, IoT gateway, industrial input/output devices, and supervisory control and data acquisition. The topics covered industrial applications, including dashboard design with cloud SCADA, data acquisition for monitoring, sequential programming with LUA script, network configuration, and pass-through for PLC. The framework of STEM education was examined and aligned with the PRSPDP learning model to formulate the learning process and activities. Before teaching, the quality of the training packages was assessed by seven experts to a high level.

The participants consisted of 134 vocational certificate students enrolled on electrical and electronic programs in 2024. The learning achievements revealed that the students' posttest results were markedly higher than their pretest scores at the .05 significance level. The evaluation results of student satisfaction with the training packages using STEM education learning indicated that the students were very satisfied. The students expressed satisfaction with the hardware and educational methods used throughout the class activities.

In future improvements, a single board computer will be integrated with the learning for convenience. No additional computer is required to conduct the teaching. The artificial intelligence for industrial use (Tabuenca et al., 2024) will be developed in the IIoT learning package. A camera will be added to the experimental package to extend its capability. STEM education and an active learning framework will be implemented for high school and undergraduate students.

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